FY02 Highlights

- Overview
- *Architecture Concepts*
- Hurdles
  - Space Transportation
  - Space Power
  - Crew Health and Safety
  - Human and Robotic Operations
  - Space Systems
- Technology Planning
- Leveraging and Partnering
- Future Direction

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Architecture Concepts

Architecture analysis provides the context, based on science objectives, to identify technology needs and requirements that can provide significant improvements in mission cost, safety, and performance. The goal is to develop common architectural element concepts that may be used as stepping stones or building blocks to multiple destinations.

FY02 Architecture Concepts Accomplishments:

- Generated recommendations for Agency-level exploration requirements
- Defined a family of Design Reference Missions that identify required capabilities to implement the NEXT exploration strategy
- Concentrated on development of system/element concepts which provide potential solutions to NEXT-identified exploration hurdles
  - Developed artificial gravity vehicle concept for travel beyond Earth's Neighborhood
  - Refined concepts for Earth's Neighborhood
    - Construction and Maintenance of Large Space Telescopes
    - Orbital Aggregation & Space Infrastructure Systems (OASIS)

Design Reference Mission: *An exploration mission description, including top-level goals, used as a template by which multiple exploration strategies and architectures may be evaluated.*

Architecture: *The operations concept and infrastructure – including ground and in-space systems – utilized to accomplish one or more distinct exploration missions.*

Architecture Concepts – Recommended NASA Exploration Requirements

NEXT has produced a requirements document – *Space Exploration Top Level Requirements* – which captures requirements that guide the planning and execution of all advanced technology investments for NASA space exploration efforts.

Requirements related to other portions of the Agency's mission were not intended to be included within this document. The goal of this document is to influence planning and development of the Agency exploration strategy, eliminate duplication of efforts in the area of technology development, and unify the Agency towards common goals. Companion lower level NEXT documents define sample design reference missions, technology road maps, performance goals/metrics, system-level requirements, gap analyses, and systems engineering processes. The NASA Strategic Plan identifies near-term priorities and longer-term investments that implement National Space Policies. In turn, Enterprise strategic plans identify policies, priorities, and requirements that implement applicable Enterprise-specific portions of the NASA Strategic Plan. The imperative for space exploration – that cuts across the Enterprises – is articulated by NASA's vision and mission statements.

These top level requirements for NASA exploration missions evolve from the overall NASA Vision and Mission stated below:

> **NASA Vision**
> *To improve life here,*
> *To extend life to there,*
> *To find life beyond.*
>
> **NASA Mission Statement**
> *To understand and protect our home planet*
> *To explore the Universe and search for life*
> *To inspire the next generation of explorers…as only NASA can.*

Recommended NASA Exploration Requirements

Draft Level 0 Requirements

- NASA shall develop an integrated strategy for the 21st century that will establish a progressive expansion for future exploration of space.
- Exploration shall be driven by fundamental science questions, modified and influenced by considerations of national interest, national security, the role of the private sector, and the role of other nations.
- Exploration shall extend cooperative human/robotic presence beyond low-Earth orbit using the unique capabilities of humans to achieve critical scientific goals and objectives.
- Exploration shall include a strategic combination of robotic presence and human presence with supporting robotic capabilities.
- NASA shall assess the safety, affordability, return on investment, and probability of success of all Exploration activities to ensure that risks are appropriately managed.
- NASA shall develop and execute a plan for strategic technology investments to enable the integrated exploration strategy, while also serving the other elements of its mission.
- NASA Education and Outreach efforts to inspire future generations of scientists and engineers, as well as the public as a whole, will be based on the mystery, wonder, and fascination inherent in exploration.

Architecture Concepts – NEXT Design Reference Missions

The NEXT strategy is to build a sustainable infrastructure that provides progressively greater and greater human/robotic exploration capability over time, and as a byproduct, supports the development of new markets using space. A diverse set of initial, science-driven, design reference missions have been selected for study which represent pure robotic to robotic/human partnering to meet multiple science goals at multiple destinations. These missions outline the means by which humans and robots may leave Earth, travel progressively to more distant destinations, and achieve the scientific objectives identified in the NEXT integrated space exploration vision.

The principal use of design reference missions is to lay the basis for comparing different approaches and criteria in order to select better ones. That is, they are used to form a template by which subsequent exploration strategies may be evaluated for consideration as alternate or complementary approaches for a given mission. When comparing architectures, specific measures of merit are considered including human health and safety, cost, performance, mission return, and schedule. With this in mind, design reference missions may be used to:

- Understand requirements for human exploration in the context of other space missions and research and development programs
- Establish an end-to-end mission baseline against which other mission and technology concepts can be compared
- Derive technology research and development plans
- Define and prioritize requirements for precursor robotic missions
- Define and prioritize flight experiments for precursor human missions, such as those involving the Space Shuttle or the International Space Station
- Open a discussion with international partners in a manner that allows identification of potential interests of the participants in specialized aspects of the missions
- Provide educational materials at all levels that can be used to explain various aspects of human interplanetary exploration and describe to the public, media, and political system the feasible, long-term visions for space exploration

The choice of the overall mission strategy has a profound influence on the safety, mission return, and subsequent cost of the exploration endeavor. Special consideration of specific mission-related design choices including the mission class, human health hazards, aborts, and mission sequencing must be made early in the mission design process. Finding the proper balance between these interrelated parameters requires stringent systems engineering processes and careful evaluation of the resulting designs and strategies.

NEXT Design Reference Missions

Architecture Concepts – System/Element Concepts for Design Reference Missions

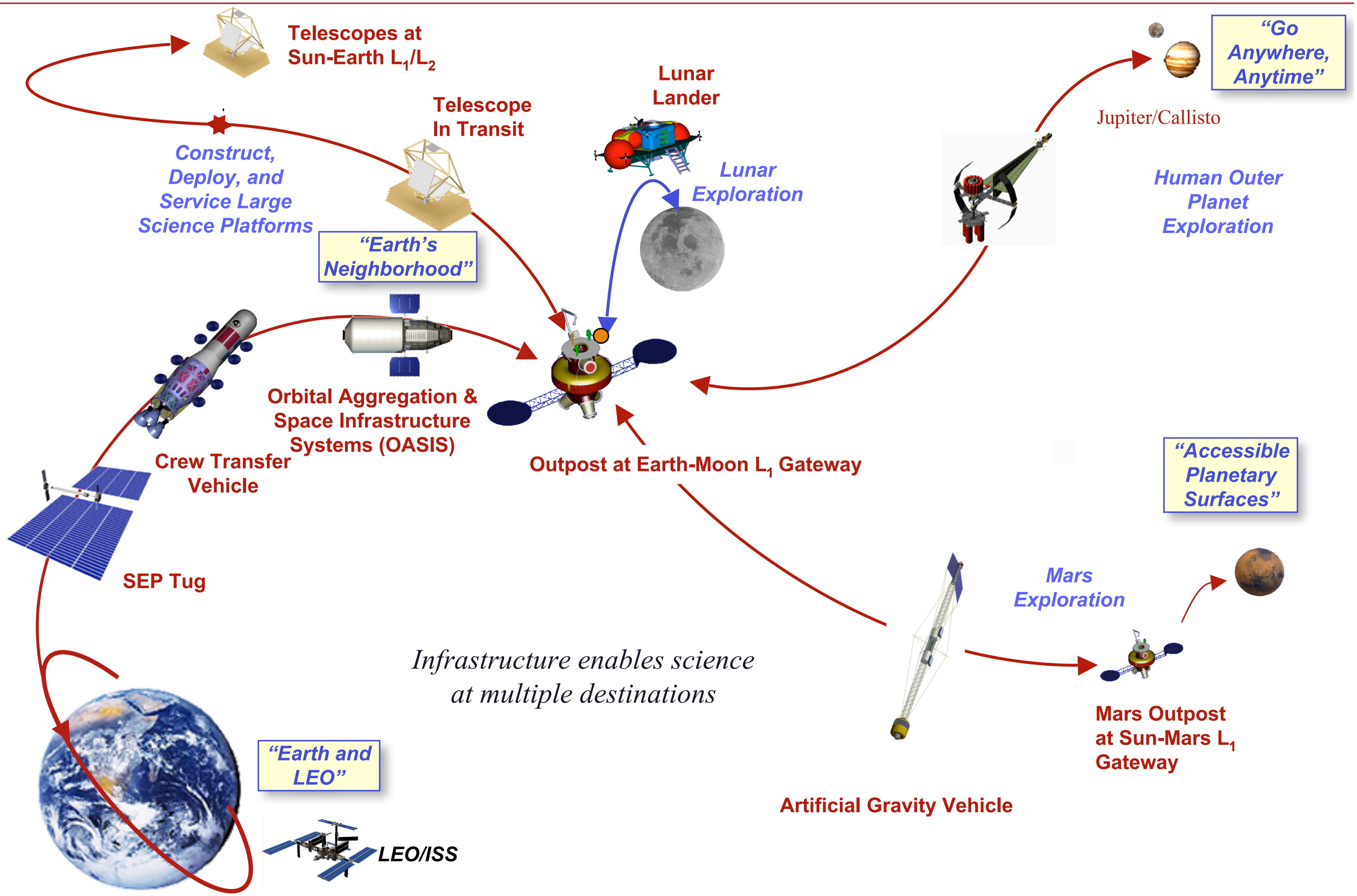
The system- and element-level concepts are developed with sufficient fidelity to provide the "proof of concept" needed to support a given architecture implementation and to help determine requirements for technology development. These concepts are not intended to be final solutions but to provide a baseline by which other element and system concepts can be compared.

The centerpiece element for operation in the Earth's Neighborhood is the Outpost at the Earth-Moon L_1 "gateway." This facility would enable the construction and maintenance of large space instrumentation, provide vehicle support for lunar surface missions, and perhaps support human exploration to deep-space destinations.

A Crew Transfer Vehicle would operate between low-Earth Orbit (perhaps based at the International Space Station) and the L_1 libration point. Depending upon the launch capacity assumed, a solar-electric tug might prove advantageous for transfer of assembled flight elements from low-Earth orbit to L_1. An alternative concept, referred to as Orbital Aggregation & Space Infrastructure Systems (OASIS), involves a hybrid chemical/electric-propulsion vehicle which would take advantage on on-orbit propellant "farms" for refueling. A lunar landing vehicle would transport crews from L_1 to the lunar surface and back..

Mars and outer planet transit vehicles, perhaps employing artificial gravity, could be assembled and refurbished at L_1. Staging locations or orbits at these deep-space destinations is a continuing trade study.

System/Element Concepts for Design Reference Missions



Architecture Concepts –
Exploration Hurdles Common to All Stepping Stone Architectures

Over the past few years in the development of the NEXT stepping stone approach and the exploration design reference missions, certain hurdles have been identified that are common across all architectures.

Foremost among these is space transportation. Human exploration beyond low-Earth orbit will require moving significant masses to high-energy orbits. Element concepts have employed high-performance technologies such as aerocapture and advanced chemical and electric propulsion. Even so, the goals set out by NEXT will exceed existing launch capabilities, and extensions of these must be explored.

Space power, especially in conjunction with electric propulsion and operations on planetary surfaces and at distances from the sun greater than 1 astronomical unit (the mean distance between the sun and Earth) will exceed the capabilities of photovoltaic systems. Nuclear power may well enable these types of missions.

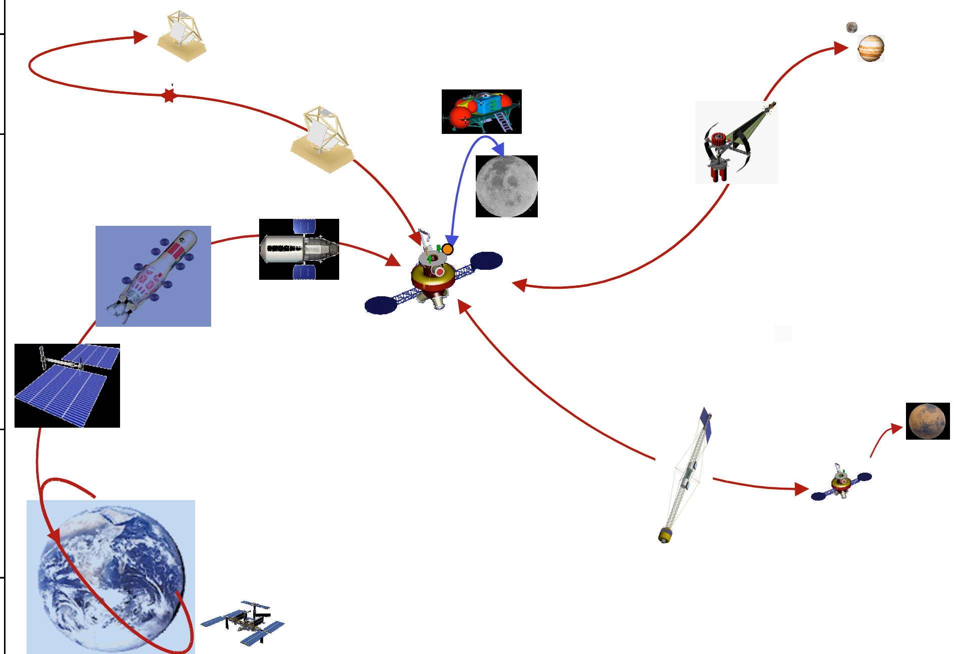
Crew health and safety is a continuing concern. All human spaceflight operations to date have been conducted under the assumption that crewmembers could return relatively quickly to Earth in case of serious injury. This will become impossible as exploration extends into deep space. Crews will be required to be self-sufficient regarding their health and safety. A great emphasis must also be made in understanding the risks associated with long-duration microgravity and deep-space radiation exposure and developing effective and safe countermeasures.

Human and robotic partnerships will be needed to effectively accomplish the goals NEXT has set forth. In-space assembly and planetary surface exploration will require augmentation of human senses, mobility, and capabilities.

Finally, all space systems supporting human exploration will require high levels of reliability and robustness. Just as the emergency return to earth will be impossible for crew medical issues, failed systems cannot be returned to Earth for inspection or repair. Optimal levels of reliability, redundancy, and repairability will need to be engineered into all human exploration systems.

Exploration Hurdles Common to All Stepping Stone Architectures

Strategic Stepping Stone	Architectural Elements
Low-Earth Orbit	- Launch Vehicles - International Space Station
Earth's Neighborhood	- Solar Electric Propulsion Tug - Crew Transfer Vehicle - Orbital Aggregation & Space Infrastructure Systems (OASIS) - Lunar Outpost - Telescopes
Accessible Planetary Surface	-Mars Crew Transfer Vehicle - Mars Outpost - Mars Lander
Sustainable Planetary Surface	- Mars Surface Habitat - Mars Surface Vehicle
Go Anywhere, Anytime	- Outer Planet Vehicle



Common Hurdles

- Space Transportation
- Power
- Crew Health & Safety
- Human & Robotic Operations
- Space Systems

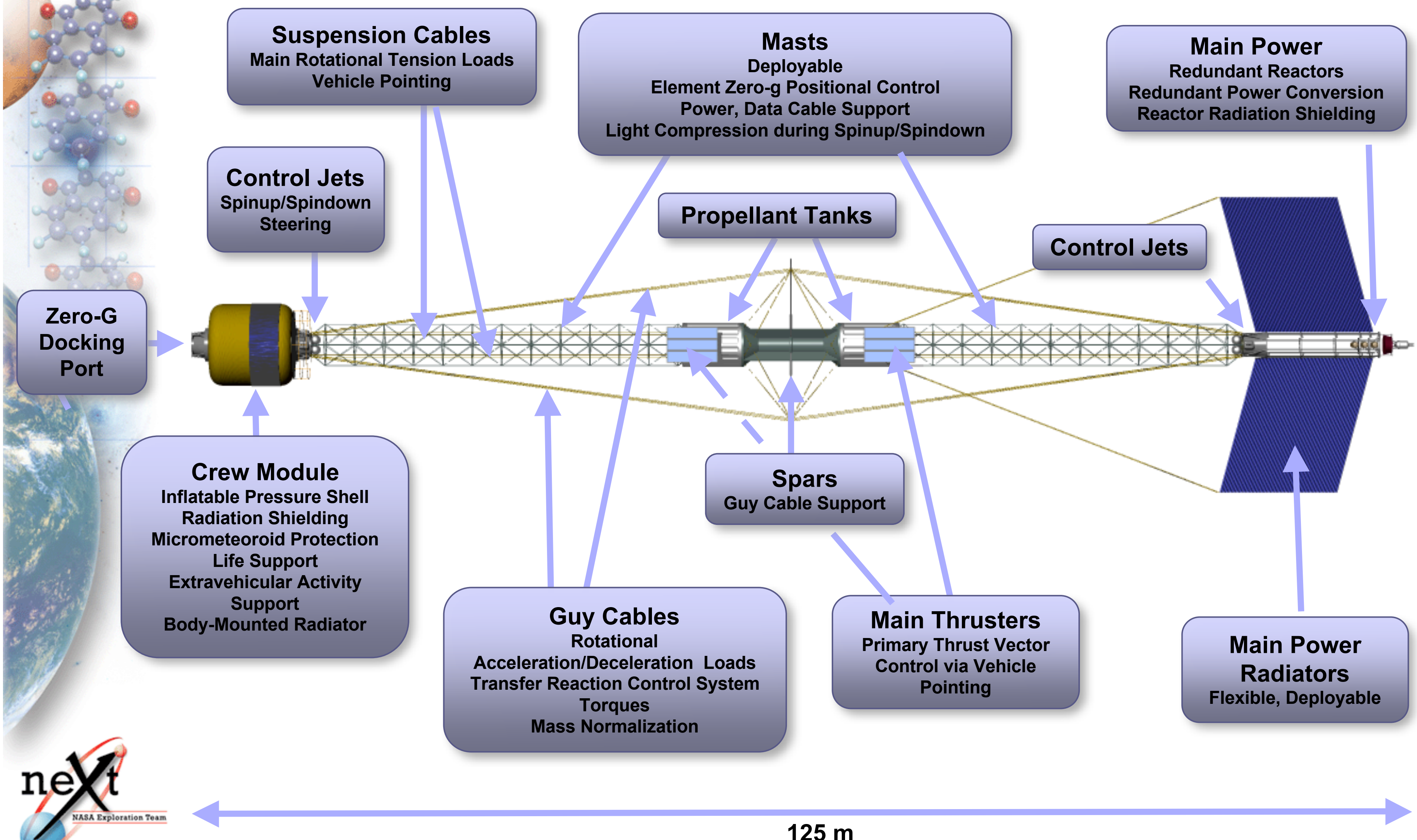
Architecture Concepts –
1-g Artificial Gravity Nuclear Electric Propulsion Vehicle

The number of past vehicle engineering studies designed to incorporate artificial gravity is not large. Two, however, were deemed compatible with current requirements and were examined for configuration concepts and operational strategies. The main differences in the two concepts centered on the system masses used to counterweight the habitation volume during rotation. One utilized the mass of the nuclear power generation and conditioning systems, while the second split the habitation volume. Both concepts feature despun propulsion systems in order to allow thrust vectoring without requiring the precession of the angular momentum associated with the rotating sections. The strategy was to align the rotation plane with the interplanetary trajectory plane, as most optimal low-thrust profiles produce planar trajectories. While this may alleviate one design issue, another presents itself. Large mechanical rotation joints are required with continuous 100 kilowatt- to megawatt-level power transmission across the interfaces. While such mechanisms are undoubtedly technically feasible, the mass, complexity, and reliability of such devices may prove challenging.

This study opted to focus initially on a simpler configuration which would potentially eliminate the need for large rotating interfaces, and examine the dynamics issues involving precession of the entire rotating vehicle for thrust vector control. To accomplish this efficiently, three top-level design goals need to be met: 1) utilize the power production and conditioning systems as a counterweight to the habitation volume to avoid ballasting or inefficient splitting of the habitat, 2) operate the power systems at gravity levels of ~1-g to simplify system qualification, and 3) achieve the propulsive performance necessary to accomplish the archetype mission with technology assumptions consistent with the "technology horizon." The implications of these goals are: 1) the power system mass must be nearly equal to the habitation system mass, and 2) the power system may assume a specific power level of 4-8 kg/kWe and the propulsion system a specific impulse of 4,000-6,000 sec.

Based on past nuclear electric propulsion (NEP) mission analysis data and habitation module design studies, it appears that all of these design goals can be met. The resulting vehicle power levels will lie in the range of 4-8 MWe.

1-g Artificial Gravity Nuclear Electric Propulsion Vehicle



Architecture Concepts –
Evolution of a Large Space Telescope

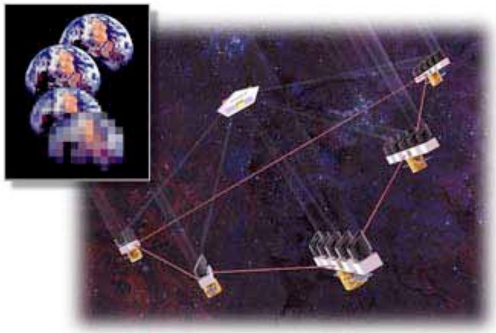
Conceptual development for future astronomical observatories begins with fundamental science themes identified by groups such as the National Academy of Sciences and NASA strategic planning committees. These themes are important for understanding how the universe and its galaxies, stars, and planets formed and evolved.

The astronomy challenges are then fed to the NEXT Exploration Science Working Group, which identifies specific scientific observations to be made to answer astronomy's fundamental questions, defines appropriate observatory aperture classes and instrument suites, and develops basic mission requirements.

Flowing down from the science teams, the NEXT Advanced Concepts Team, working in conjunction with the science and human-robot cooperation working groups, then develops potential mission concepts and representative observatory designs to accomplish the objectives set forth. For example, several advanced science platform concepts are presently under development, including the Filled Aperture Infrared (FAIR) Telescope concept, a large-aperture far-infrared and sub-millimeter telescope to meet anticipated high-priority science objectives. This conceptual development work includes human-robot collaboration study, trade analysis, technology identification, mission planning and sequencing, and element design. NEXT is currently performing studies assessing optimized assembly, deployment, and servicing of the FAIR telescope.

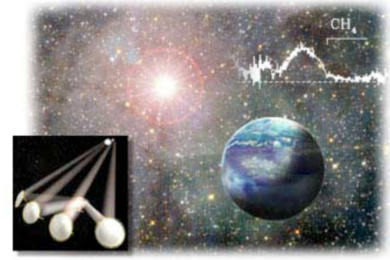
Architecture Concepts

Evolution of a Large Space Telescope



Science Challenges

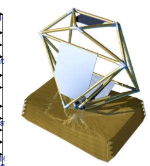
- Understand the structure of the universe
- Learn how galaxies, stars, and planets form, interact, and evolve
- Look for signs of life in other planetary systems



Science Working Group

- Scientific Observations
- Requirements
- Instrument Definition
- Contamination Environment

Aperture	Equivalent collecting area to 10 circular telescope
Spectral Range	40-500 microns
Surface Quality	3 microns
Pointing Stability	0.1 arcsec for > 2000 sec integrat times
Optics Temperature	Passively cooled to < 30 K
Detector Temperature	0.1 K bolometers, 1.5 K photoconductors
Lifetime	5 years minimum
Observing Modes	Greater than or equal to 1 hr s
Slew Rates	~5 degree/minute
Polarization	< 1%
Instrumentation	Imagers; spectrometers (R ~ 1 100000) & (R ~ 1X5E6) resolution



Advanced Concepts Team

- L_1 Outpost Assembly, Deployment & Servicing
- Gossamer Structures
- Mission Planning
- Assembly Sequencing & Task Development

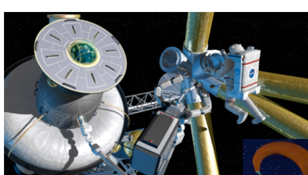
Telescope Design Team

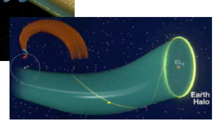
- Optical Properties & Requirements
- Configuration

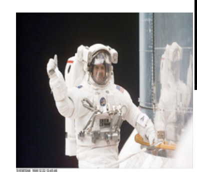
Human/Robotic Working Group

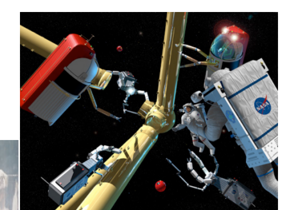
Optimization Studies

- In-space Extravehicular Activity/Robotic Construction Analysis
- Technology Identification
- Automation vs. Assembly









Architecture Concepts –
An OASIS-Enabled, ISS-Aligned Space Commercialization Scenario

Orbital Aggregation & Space Infrastructure Systems (OASIS) is an in-space architecture concept consisting of highly reusable systems and resources that provide a common infrastructure for enabling a large class of space missions. The OASIS architecture minimizes point designs of elements for focused space mission objectives and maximizes modularity, reusability, and commonality of elements across many missions, enterprises, and organizations. The economic feasibility of these concepts is dependent on the availability of a low-cost launch vehicle for delivery of propellant and resupply logistics. The anticipated benefits of synergistic utilization of space infrastructure are reduced future mission costs and increased mission flexibility for future space exploration and commercialization initiatives.

FY01 Revolutionary Aerospace Systems Concepts (RASC)-funded OASIS studies focused on preliminary design of the architecture systems, analysis of Lunar Outpost and commercial mission scenarios, and preliminary analysis of economic viability.

FY02 NEXT-funded activities included the preliminary costing of OASIS systems, development of an OASIS-based space commercialization scenario, and parametric assessment of the economic factors needed to provide a commercially viable space industry.

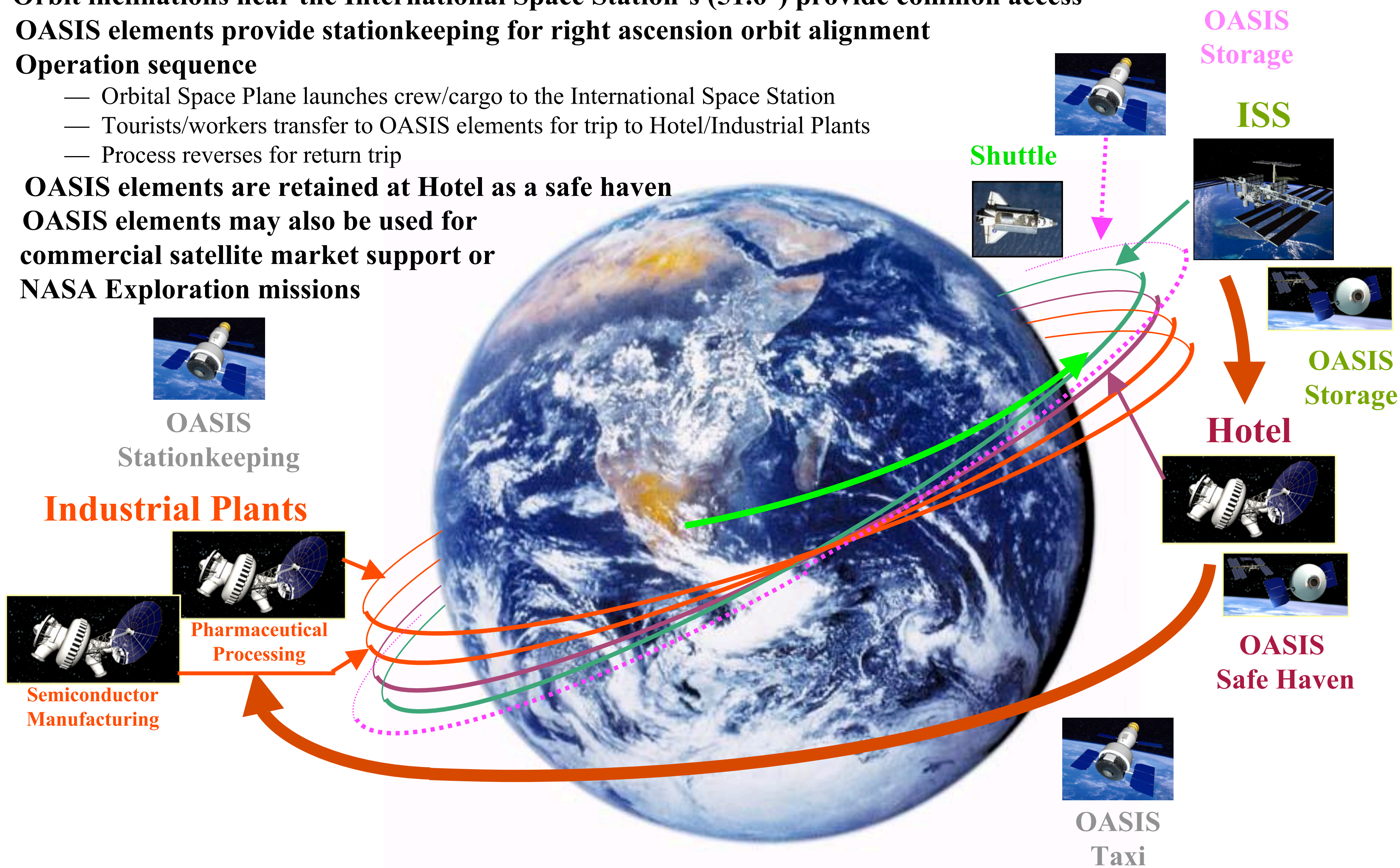
Study results have quantified the potential benefits of OASIS as a reusable, multi-mission architecture. In addition to supporting Earth's Neighborhood exploration missions – including low-Earth orbit staging from the International Space Station and routine sorties to the Lunar Outpost at the L_1 libration point – OASIS may support commercial and Department of Defense missions as well. These applications include satellite delivery and servicing (refueling, refurbishing, and positioning), and support of Earth-orbiting commercial outposts. Commercial outposts may function as industrial processing plants or hotels enabling space tourism.

The integrated, NASA-commercial OASIS traffic model includes:

- 62 total missions per year (4 for Exploration, 58 for commercial purposes)
- 50 propellant resupply launches per year
- Commercial use rate of ~10 missions per year per element (Hybrid Propellant Module)

An OASIS-Enabled, ISS-Aligned Space Commercialization Scenario

- Orbit inclinations near the International Space Station's (51.6°) provide common access
- OASIS elements provide stationkeeping for right ascension orbit alignment
- Operation sequence
  - Orbital Space Plane launches crew/cargo to the International Space Station
  - Tourists/workers transfer to OASIS elements for trip to Hotel/Industrial Plants
  - Process reverses for return trip
- OASIS elements are retained at Hotel as a safe haven
- OASIS elements may also be used for commercial satellite market support or NASA Exploration missions



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